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Monitoring system of the front of the melt crystallization

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A system for automatic determination of the position of the crystallization front in the process of growing sapphire crystals by horizontal directed crystallization (HDC) has been developed. The images of the crystallization process can be transmitted to the operator display simultaneously from several growth installations. The proposed method of CF monitoring allows control of the CF location efficiently and without interference in the design of the growth unit.

Разработана система автоматизированного определения положения фронта кристаллизации в процессе выращивания кристаллов сапфира методом горизонтальной направленной кристаллизации. Изображение процесса кристаллизации передается на экран оператора одновременно с нескольких установок. Предложенная методика и оборудование для определения положения фронта кристаллизации может быть использована без вмешательства в конструкцию ростовой установки.

1.Introduction

In crystal growth by the horizontal directed crystallization (HDC) method, one of the problems is monitoring of the crystallization front (CF) location [1]. Conventionally this monitoring is carried out by visual methods through an observation window. In [2], monitoring of the CF location was carried out using high-speed cameras. However, the available camera software does not allow processing of the images obtained in the course of the growth process. Therefore, the image analysis and determining of the CF location could be made only after the growth. Such a system is not suitable for dynamic control of CF changes.

The main objective of this work was development of a method and appropriate installation design for clear and unambiguous determination of the location of the crystallization front in the course of HDC crystal growth in the online mode.

2. Experimental and results

The proposed design includes an optical surveillance system mounted directly inside the housing of the growth installation above the inspection window. Manual focus and zoom lens allows accurate allocation of the area of interest and obtaining the images suitable for computer processing. Alongside with the data transfer, the image is transferred onto a display screen for the operator of the process. The image can be transmitted simultaneously from multiple growth units.

Control of changes in CF location can be performed automatically, that is, the detection of CF location does not require manual setting of location markers. In some cases, this location can be set manually indicating

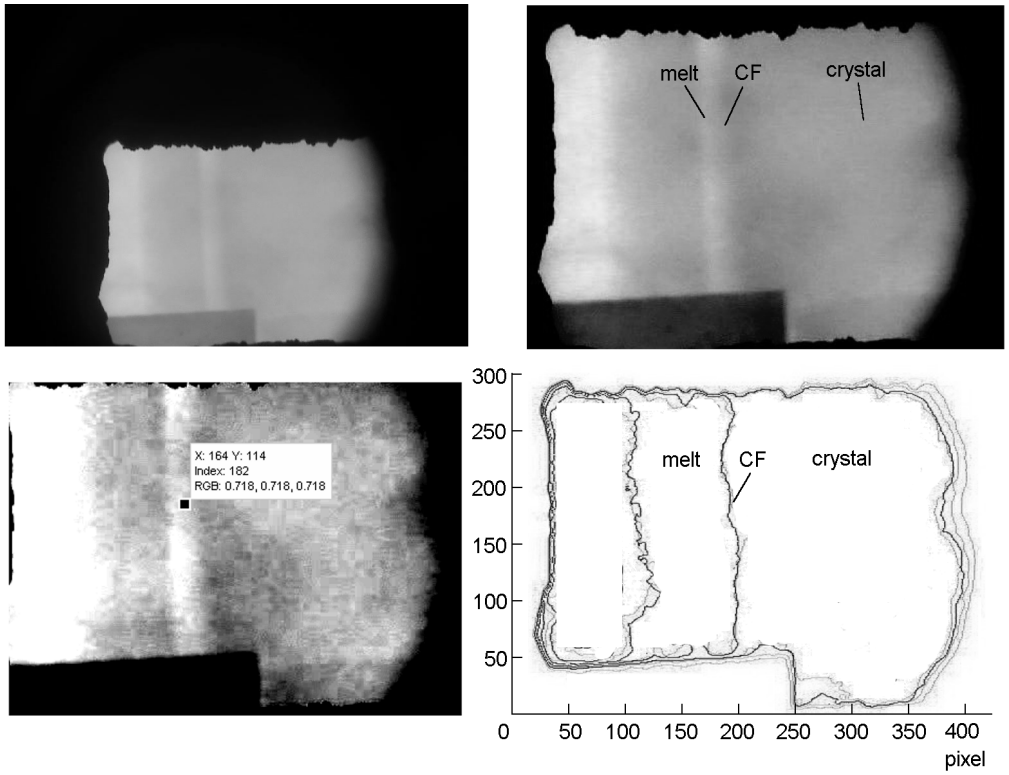

Fig.1 Image processing steps: a – original image; b – cropped and filtered image; c – the image with changed density; d – the image with a distinguished contour.

the response zone (this can be used when active control of the CF location is required.)

The crystal quality is directly related to the nature of CF movements [2]. Review and analysis of the archive of CF images obtained during the growth cycle can suggest the presence of defects of various types in the grown crystal. The image processing algorithm consists of several steps to improve the image quality and determine the location of the crystallization front.

The general scheme consists of the following stages: initial configuration of the camera carried out on the bench before installation, selection of a specific region of interest and approximation of the field space depth. Fine substring image quality was obtained on a computer monitor from the camera on the growing unit.

The sizes of all objects within the image area was measured by a test image.

Image processing was performed in a freeware program Scilab.

Scilab Image Processing toolbox is intended to do imaging tasks such as filtering, blurring, edge detection, thresholding, histogram manipulation, segmentation, mathematical morphology, color image processing, etc [3].

Image processing. Decomposition of images by color (RGB) can distinguish the color channel in which the image is more clear and sharp. Our studies have shown that the most clear image of the front location is achieved with the mix of green and red channels at the ratio of 70 to 30% , respectively. The resulting image after channel aggregation is presented in shades of gray. Arithmetic operations for combining images were used to obtain the final image.

The resulting image is exposed to processing by a median filter to reduce noises that are present in the source.

Rotation and shift of the images is made produced by a well-pronounced element of the image that remained stable throughout the experiment. This allows compensation for image shaking [4].

To highlight the crystallization front on the image, adjustment of the image color density was carried out. Graphic information about the crystallization front is contained in a a narrow range of brightness grades. Dynamic adjustment of brightness was used to reliably determine the limits of variation of color intensity used for imaging the crystallization front [5].

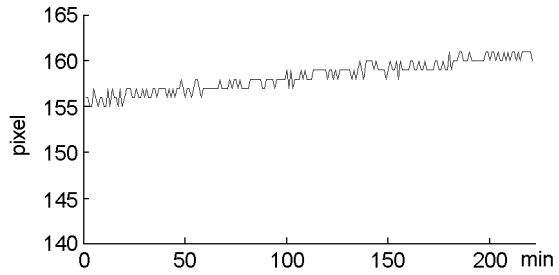

Fig.2. Shift of the crystallization front in the crystal growth process.

For automatic singling out of the CF location, conversion of the obtained images to contour image was carried out. The contour lines indicate the boundaries of sharp changes in color density (Fig. 1.d).

Because the image has a stable density within the boundaries of static objects, the path of the contour movement gives information on the status of the crystallization front.

Since the image is normalized, the coordinates of the shifted contour give the numerical values characterizing the crystallization front. It is convenient to measure this position in pixels from the edges of the image. The absolute value of the position of the crystallization front is accurately reconstructed from the known values of the size of the reference image.

3. Conclusion

Experimental measurement of the position of the crystallization front have shown that during the growth process the front is gradually moving (Fig. 2.). The error in determining the position of the front by the reported method does not exceed 0.25 mm.

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Система контролю положення фронту кристалізації розплава

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Розроблено систему автоматизованого визначення положення фронту кристалізації в процесі вирощування кристалів сапфиру методом горизонтальної направленої кристалізації. Зображення процесу кристалізації передається на екран оператора одночасно з кілької установок. Методика і обладнання для визначення положення фронта кристалізації використовуються без втручання в конструкцію ростової печі.